BIOSTRATIGRAPHY AND SEDIMENTARY EVOLUTION OF CONTINENTAL NEOGENE IN THE MADRID AREA

by

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RESUME – **Biostratigraphie et évolution sédimentologique du Néogène Continental de la région de Madrid.** Dans ce travail on étudie le Miocène inférieur et moyen de la région de Madrid. La sédimentation de cette zone du bassin du Tajo correspond à un dépôt endoréique alimenté par des "alluvial fans" provenant de la chaîne centrale espagnole qui, après des faciès de transition, passent aux évaporites lacustres vers le centre du bassin. On peut distinguer dans la disposition de ces dépôts trois unités sédimentaires : inférieure, intermédiaire et supérieure. La base de l'unité inférieure a été datée seulement par des micrommamifères fossiles provenant de sondages. On lui attribue un âge oligo-miocène. L'ensemble des faunes de Madrid et du couloir Madrid-Guadalajara correspond au Miocène moyen (Aragonien), elles se placent toutes dans l'Unité intermédiaire. Cet ensemble peut être subdivisé en deux groupes : l'un d'âge Aragonien moyen et l'autre d'âge Aragonien supérieur. La discontinuité majeure entre l'Unité inférieure et l'Unité intermédiaire se place donc au-dessous de l'ensemble des faunes de l'Aragonien moyen et correspond à la phase Neocastellana (cf. AGUIRRE *et al.*, 1982). La discontinuité entre l'Unité intermédiaire et l'Unité supérieure est représentée par une discordance d'érosion. L'Unité supérieure est très complexe et contient des éléments inutilisables pour la datation. La faune de Cendejas à *Hipparion* et *Decennatherium* peut-être attribuée au Vallésien. Au-dessus de cette Unité la faune du remplissage karstique avec *Valerymys turoliensis, Stephanomys rambliensis, Occitanomys adroveri* et *Apodemus* cf. *gudrunae* permet de vieillir dans le Ventien (Miocène terminal) la phase tectonique (Iberomanchega) qui plisse le "Páramo". L'évolution sédimentologique de ce bassin met en évidence l'existence d'un changement climatique progressif, de conditions arides à humides, de l'Aragonien inférieur au Vallésien. Les faunes de l'Aragonien de l'aire étudiée correspondent, en général, à un paysage ouvert avec de remarquables différences d'humidité. Biogéographiquement elles présentent de grandes affinités avec celles du bassin de Calatayud-Daroca.

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SUMMARY – This is a study of the Lower and Middle Miocene in the area of Madrid. Sedimentation in this zone of the Tajo Basin corresponds to endorheic deposits fed by alluvial fans from the Sistema Central which, after transition facies, flow into the centre of the basin. Three sedimentary units can be distinguished throughout the distribution of these deposits : Lower, Intermediate and Upper. The base of the Lower Unit has been dated only by mammals fossils from drillings. It has been attributed to the Oligo-Miocene. The fauna groups of Madrid and the Madrid-Guadalajara Corridor correspond to the Middle Miocene (Aragonian) and all are located in the Intermediate Unit. Two groups can be distinguished, one of Middle Aragonian age and the other of Upper Aragonian. The major discontinuity between the Lower and Intermediate Units is, thus, located below the fauna group of the Middle Aragonian and corresponds to the Neocastellana phase, as it had already been said by AGUIRRE *et al.*, 1982. The discontinuity between the Intermediate and Upper Units is represented by an erosive unconformity. The Upper Unit is very complex and contains rare dating elements. The fauna of Cendejas with *Hipparion* and *Decennatherium* is attributed to the Vallesian. Above this Unit, the fauna of karstic filling with *Valerymys turoliensis, Stephanomys rambliensis, Occitanomys adroveri* and *Apodemus* cf. *gudrunae* allows an infradating in the Ventian (Terminal Miocene), of the tectonic phase (Iberomanchega) which folds the "plateau". The sedimentological evolution of the basin clearly shows a progressive climatic change from arid to moist conditions, between the Lower Aragonian and the Vallesian. The fauna of the Aragonian in the studied area corresponds, in general, to an open landscape with notable differences of humidity. Biogeographically, their closest counterparts are those of the Calatayud-Daroca basin.

INTRODUCTION

The Madrid Tertiary Basin, also called the Tajo Basin, is a result of a wide depression of tectonic origin, with an extension of more than 20 000 km^2 and infrequent reliefs dominated by wide plains called "plateau" which form what constitutes, from a geographical point of view, the meridional Plateau in Castilla la Nueva. Its triangular shape is surrounded by mountainous reliefs : on the western side from NE to SW the Sistema Central ; to the east, from N to S, the Sierra de Altomira and to the S the Montes de Toledo.

The Madrid Basin, of endorheic characteristics, is almost completely filled by Paleogenic and Neogenic sediments which lie over a substratum of Cretaceous materials and in their turn rest on the crystalline basement. These deposits have been the subject of various studies, since the last century, local and specific studies as well as those of a more wide-ranging nature, which have given us the knowledge we have now on the basin. At the level of stratigraphic synthesis, the first study is the work of ROYO (1926) and, later on, that of RIBA (1957) who established a sedimentary model based on lateral facies changes. Subsequently, using this model, MARTIN ESCORZA (1976) points out the presence of a series of lithostratigraphic units (M1 to M5) and the existence of six erosive unconformities of tectonic origin. Of these unconformities, AGUIRRE *et al.* (1976) date S1, S2 and S3 and propose that the tectonic phases which originated them shall be called, the Castellana, Neocastellena and Intravallesiense phases. Recently MARTIN ESCORZA & BUSTILLO (1979) and MEGIAS *et al.* (1979) presented very different synthesis in project 25 of the IGCP (UNESCO, IUGS), the first one, based on their previous studies, following RIBA sedimentary model (*l.c.*) and the second summarising a model already presented by them at the IX National Sedimentology Congress in Salamanca and at the International Geological Congress in Paris (1980) (MEGIAS *et al.*, 1980a, b).

Our area of study is restricted to Madrid and its surrounding areas, bordered by Paracuellos de Jarama and Alcalá de Henares in the N and E, the

mouth of the river Manzanares in Jarama to the S and Getafe to the W. Therefore, as far as the location of the basin is concerned, we are at about 20 km from the northwestern granite edge, in an area of great variety of facies and lateral changes. It is also the place where the majority of the vertebrate localities known in the whole basin are to be found (Fig. 1 and 3).

The object of this study is mainly to establish a lithostratigraphic sequence in which we can situate the various mammalian localities and carry out a sedimentological analysis which would allow us to determine the palaeogeographic characteristics of the basin in this area.

LITHOSTRATIGRAPHIC UNITS

The continental sedimentation of this area in the Tajo Basin corresponds to endorheic deposits fed by alluvial fans from the Sistema Central which, after several complex intermediate transition facies, lead to lacustrine, evaporite and carbonate chemical sediments towards the centre of the basin.

The general structure of these materials is subhorizontal towards the centre of the basin and with a dip starting from the North area of Madrid. This dip becomes increasingly marked towards the edge due to a greater subsidence in this area.

The distribution of facies in the Madrid area shows peculiar characteristics in comparison with the other environments of the Tajo Basin. This is attributable to the specific morphology of the lacustrine environment in the area during the lower Miocene and at the beginning of the middle Miocene, with an entry towards the edge of the basin, as can be seen in fig. 1. In principle, this geometry is due to the behaviour of the edge of the basin as compared with the other areas of the same ; viz. the mountain front in the Colmenar Viejo area rises high enough and/or sinks the Guadalix ditch, thus preventing the access of clastic sediment materials coming from the Sierra de Guadarrama. This does not imply that the Colmenar relief does not behave as a positive area although it produces a smaller quantity of supplies and consequently a decreased penetration of clastic sediments with greater expansion of the lacustrine area.

In view of the sedimentary characteristics and lithology we have distinguished three lithostratigraphical units for the Madrid area.

Lower Unit

This unit constitutes the lowest observable deposits in the Madrid area. The lower limit is located in the region of Alcobendas area at a depth of 600 m, dated by Oligo-Miocene fauna. The upper limit can be seen to the SW and S of Madrid, on the left side of the Manzanares River and La Marañosa, as well as in the East, in the Cerro del Viso.

The materials which constitute this unit present a NW-SE direction of supply with three types of lithofacies distinguishable is them as follows :

Clastic sediment facies. – Constituted by alluvial fan deposits (medium and distal) with debris flow, mud flow, sheet flood and distributory channels. These materials are of arkose nature very immature and heterometric with high clay content. They present abundant hydromorphic phenomena and, in distal areas, pedologic crusts processes. They change laterally to the intermediate facies.

In the studied area they can be observed only by drilling. Nevertheless, since clastic sediment facies constitute a diachronic formation with characteristics which are very similar, as far as their origin, means of transportation and sedimentation are concerned, they will be repeated throughout the whole Miocene.

Intermediate facies. – They constitute the materials which connect the clastic sediment facies with the evaporite facies of the centre of the basin, by means of a mud-flat, that shows the following characteristics :

- clayey nature ;
- stratification in banks of variable thickness, not exceeding 1 m, generally massive and occasionally with parallel decimetric or millimetric laminations ;
- abundant bioturbation (predominance of roots) ;
- high lateral continuity of the lithosomes ;
- abundant presence of pedologic phenomena ;
- high content of organic matter.

In areas near the clastic sediment facies there are intercalations of micaceous sand of medium and fine grain, homometric, generally of centimetric thickness, with a flat base and of great lateral continuity. In this zone levels of sepiolites of metric thickness may also be seen.

These intermediate facies are located between lines 1 and 2 in fig. 1. There are many outcrops in the Tajo Basin although limited to this area and their lateral transition to gypsum may be observed to the south of the Cerro Negro, in the San Fernando de Henares area. Outcrops may also be seen at the base of the Cerro del Viso (Fig. 2).

These materials, which in the whole basin in general show great homogeneity, have different characteristics in the area situated at the NE of the Cerro del Viso, due to the different nature of the source area (quartzite and slate) (Fig. 1). These differences are accentuated in the areas nearest to the clastic sediment facies, where, they change laterally to the Guadalajara muds.

Evaporite facies. – In the studied area these facies are represented by gypsum and anhydrite with frequent intercalations of decimetric and millimetric levels, of green clay, sometimes with high content of organic matter and presence of soluble salts in the central areas of this unit (GARCIA DEL CURA *et al.*, 1979 ; ORTI CABO *et al.*, 1979 ; ORTI CABO & PUEYO MUR, 1980 ; ORTI CABO, 1982). These gypsum have different sedimentological and petrological characteristics according to their location in the area of the basin.

The environment of deposit are the ephemeral salt lakes and sebkhas, the latter occuring towards the edges of the lacustrine area and on top of the sequence.

The outcrop in these facies in the studied area are widely represented in the southern zone (Vallecas, Manzanares River, Mejorada del Campo) and correspond to the higher sections of this unit where sebkha environments are prevalent, sometimes inter-related with one another.

Contact between the lower and intermediate units. – The materials of both units are connected by means of an unconformity which shows different characteristics for different areas of the basin. In the studied area they are defined by the following facts :

1.– Progressive and generalised penetration of clastic sediment materials (coarse), in the central basin area, penetrating several kilometres over evaporite facies of the "lower unit" (Fig. 1 and 2). This is brought about by a reactivation of the

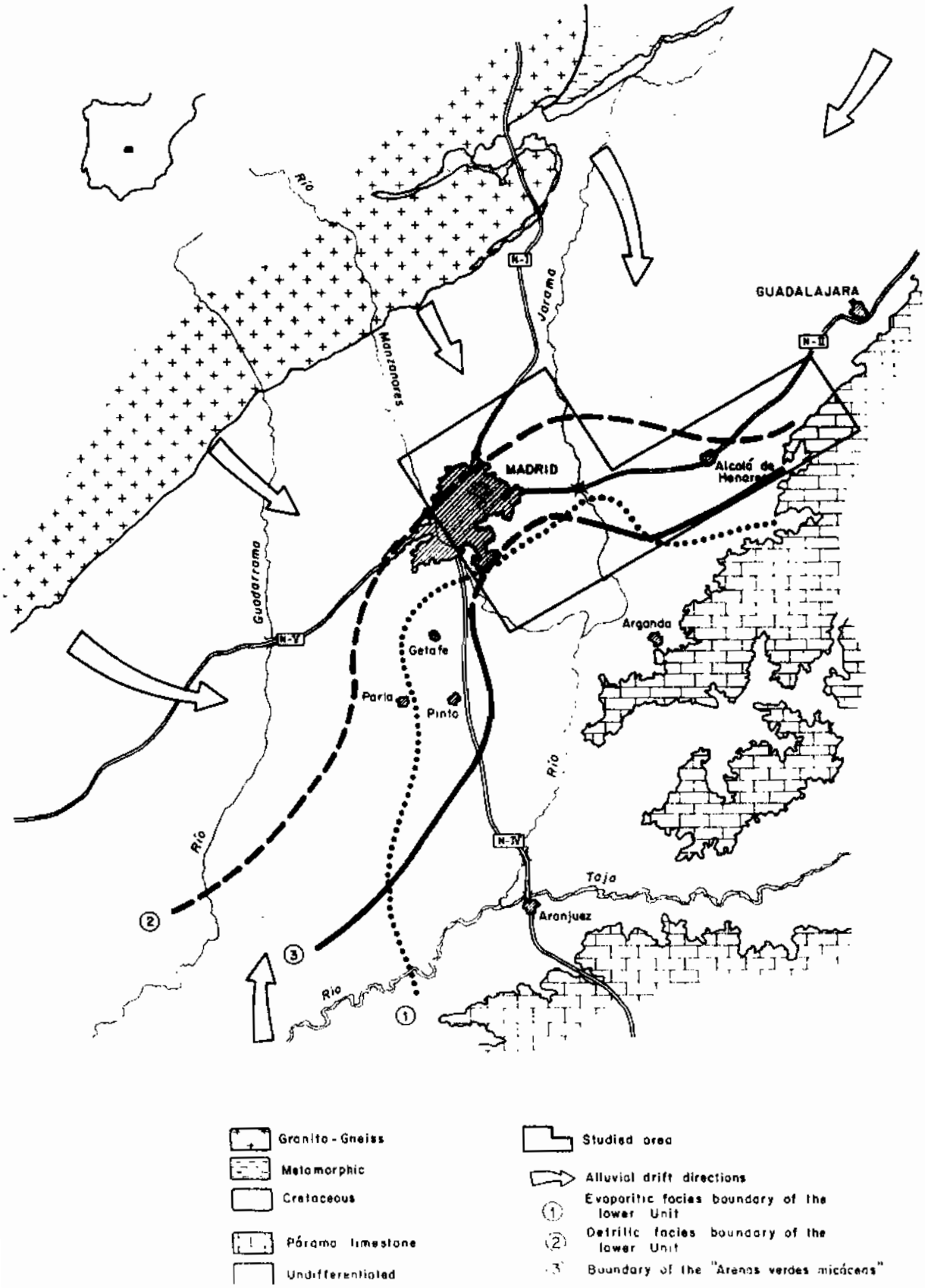

Fig. 1 - Geographic situation of the studied area.

relief. This phenomenon is not apparent in the whole of the Madrid area, since, as we have shown earlier, it has distinctive characteristics. There are, however, several points to the south and est of Madrid, where this phenomenon can be observed (south of Vallecas and the area of Alcalá de Henares). Both units appear in paraconformity or with local erosive contact.

2.– Change in sedimentation characteristics ; sedimentation in the border zones continues to occur by means of a system of alluvial fans and no changes can be observed between the two units. Nevertheless, in the distal areas and intermediate facies, it is possible to recognize a change in the sedimentation shown as follows :

- the type of sedimentation produced in the "lower unit" by means of a mud flat (in the intermediate facies), is produced in the following unit by means of a fan delta system. The most representative facies here are the micaceous sands and green clay. This type of sedimentation is produced throughout most of the "intermediate unit", due to the constant onlapping of the fans towards the centre of the basin.

- as regards the chemical facies, the type of sedimentation also changes from sebkha to marshy-lacustrine. This can be seen towards the south of Madrid (Vallecas-Almodovar-C. Mirones-La Marañosa-C. Telégrafo).

3.– Chemical change. The most important geochemical change is characterized by the generalized presence of carbonates ; previously almost non-existent in the "lower unit".
Significant reduction of sulphates, almost exclusively limited to the central areas of the basin.
Disappearance of soluble salts.

4.– Presence of karstification phenomena with exo-karstic characteristics, affecting the gypsum in the "lower unit". The uncorformity between the "lower and intermediate units", which we make correspond to the Neocastellana Phase, is attributed in the area of Madrid to middle Aragonian (MN 4/5) but, for the moment, the fauna offers no greater accuracy to date it. This presents a problem with regard to the age attributed to this unconformity in previous studies (AGUIRRE *et al.*, 1976 ; DIAZ MOLINA & LOPEZ MARTINEZ, 1979).

Intermediate Unit

The lower limit of this unit has been described previously, and the upper limit, still in the area of study, can only be seen in the Cerro del Viso, although it is widely represented, in most parts of the Tajo Basin, by an erosive unconformity.

The directions of the palaeocurrents are similar to those of the "lower unit" and thus three lithofacies can be distinguished :

Clastic sediment facies. – These facies continue with similar characteristics to those in the lower unit with the following distinctive characteristics observable for this unit :

- although they continue to be of arkosic nature, they are more highly evolved, rather better classified and with lower matrix proportions. The latter, which, in the "lower unit", showed strong and varying colours, has softer and homogenous colours, from greyish-green to light brown in this unit.

- significant onlapping of clastic sediment materials towards the centre of the basin (see line 3 of Fig. 1).

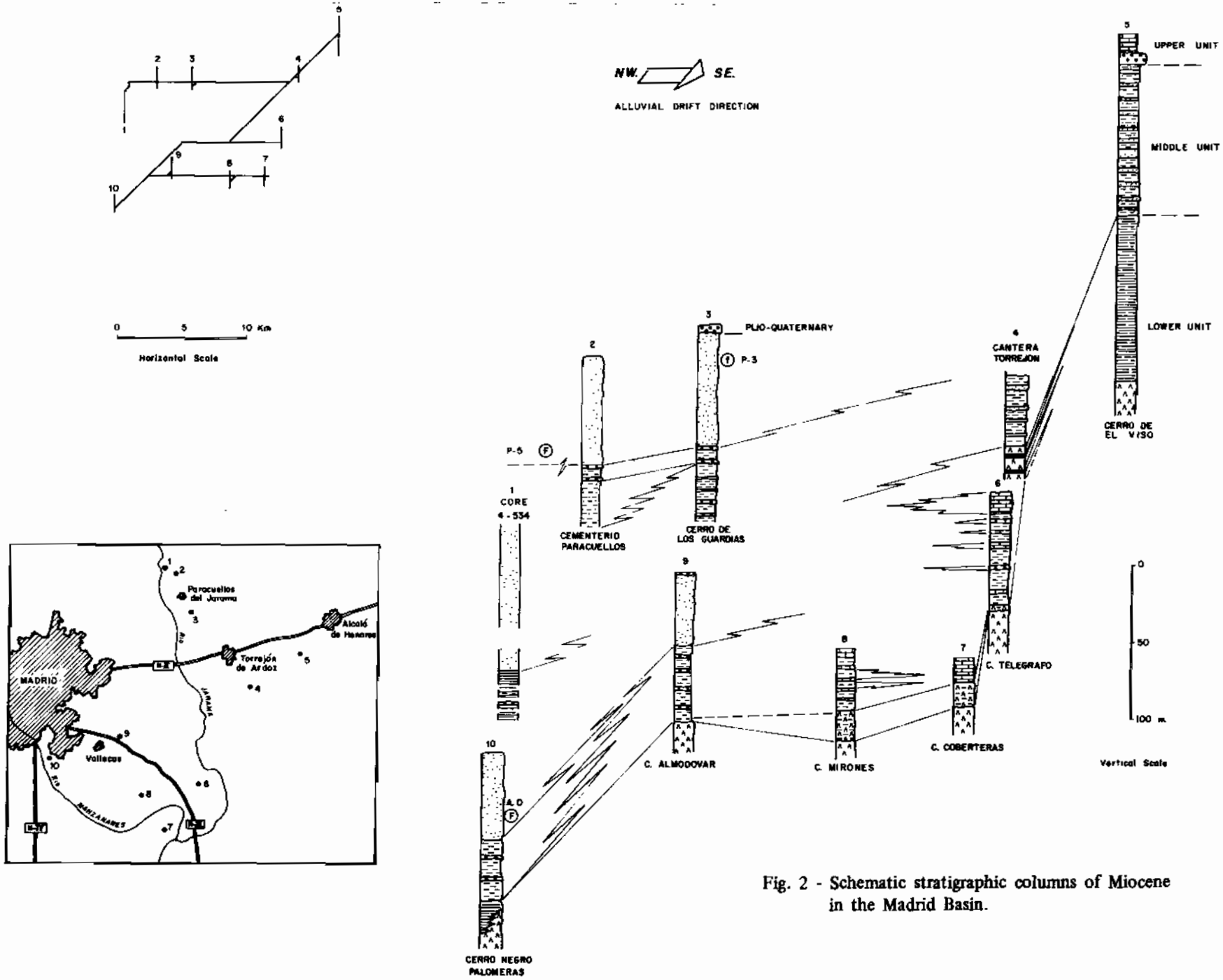

Fig. 2 - Schematic stratigraphic columns of Miocene in the Madrid Basin.

- presence of large crusts of pedologic type throughout the whole basin and calcimorphous palaeosol.

- lower degree of aridity than in the previous unit.

- greater abundance of silex and sepiolites, and dolomites in the areas of contact with the intermediate facies.

As has been mentioned previously, in the "lower unit", sediments with different lithological and petrographical characteristics are produced, although sedimentation comes about by the same deposit and sedimentation process (a system of alluvial fans). This is due to different nature of the source area between the sediments from the Mesozoic, Palaeozoic and metamorphic materials of the Sistema Central and the deposits from igneous material (Fig. 1).

The deposits from igneous materials correspond to those described in the clastic sediment facies of the "lower unit" . Those coming from metamorphic, Paleozoic and Mesozoic materials have similar characteristics but with greater abundance of fine grains (sandy muds) which slightly modify the behaviour of the deposit.

In these facies the localities of Paracuellos 3, Paracuellos 5, Arroyo del Olivar and Puente de Vallecas (Vallecas) are to be found. The lithostratigraphic situation of tnose localities is shown in Fig. 2 ; they are associated with the following kinds of sediment :

- Arroyo del Olivar : macromammals-sediments from sand and gravel channels ;
  micromammals-mud streams. Distal fan facies, mud flat. Valid for "Traperos".
- Vallecas : flat based channels, sheet flow, removal of fan lobes.
- Paracuellos 3 : sandy mud, mud flow.
- Paracuellos 5 : carbonated mud, pool edges among sandy channels.
- Henares II : cross-bedding sands ; the channel cuts into a macropool.
- Henares I : sandy channels and mud flow.

Intermediate facies. – In this unit we have also given the name of intermediate facies to the sediments which connect clastic sediment facies with marshy and lacustrine sediments. Sedimentation is onlapping in character troughout most of the development of this unit and periodically invades the flooding zones at the edges of the marshy-lacustrine area.

The characteristics of these sediments in the Madrid area are also peculiar because of the shape of the entry towards the relief in the marshy-lacustrine area, as mentioned previously. In other areas of the basin and the SW and NE flanks of the area of study, the "green micaceous sands"(1) appear well developed due to the fan delta system. Nevertheless, in the Madrid area, we find green clay in banks of 0,5 to 2 m, sometimes with abundant bioturbations and massive appearance, with intercalations of lenticular carbonated levels, sometimes with great lateral extension, which, in most cases, corresponds to calcareous crusts, of pedological nature. Associated with these, silex and sepiolites appear sporadically. Decimetric intercalations of "green micaceous sands" are frequently found in the area of transition with the previous facies.

(1) 10 m or more in thickness in Pinto, homometric, from medium to fine grain, the latter being predominant, abundant biotite, with internal sedimentary structures, generally with a flat base and wide lateral extension in relation to the thickness .

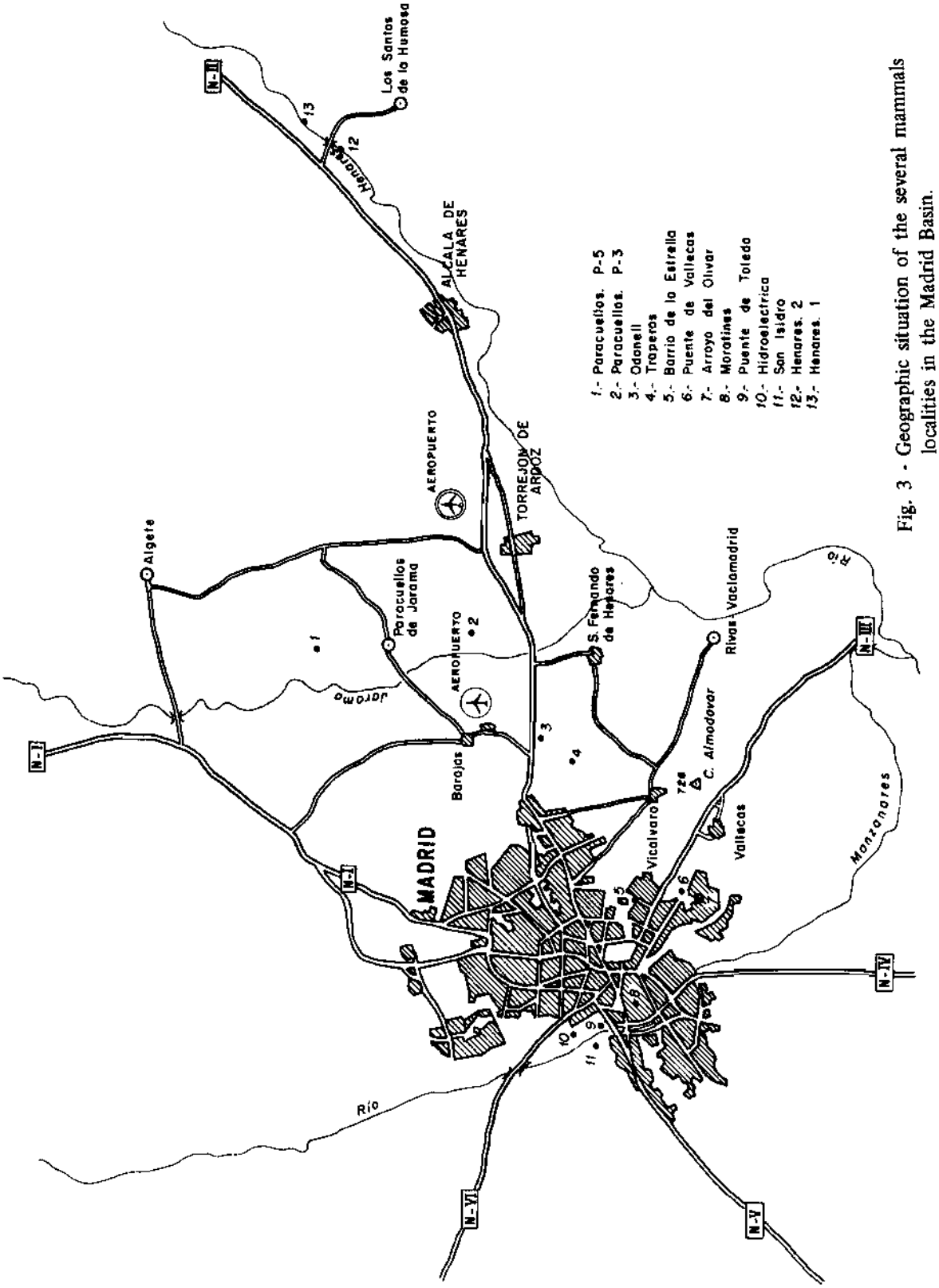

Fig. 3 - Geographic situation of the several mammals localities in the Madrid Basin.

In these facies we find the majority of the typical Madrid deposits, the sedimentary characteristics of which correspond to :

- Moratines : muds, associated with fine micaceous sands ; pond edge.
- O'Donell : clay with laminations, bioturbations of Fe and Mn oxide ; associated with fine sands ; pond edge.
- Hidroeléctrica, S. Isidro, Pte. Toledo : marls - marshy clayey ; temporarily flooded areas, siliceous and carbonated, occasionally gypsiferous flaked crusts.

Marshy-lacustrine facies

The sediments in this facies (marshy and lacustrine environments) correspond to the lateral change in the intermediate facies. They rest with unconformity on materials of the "lower unit".

They are basically carbonated in character with clayey intercalations of variable thickness. They are included variety of limestone types. These limestones are conditioned by the different existing sub-environments. Towards the base, the presence of abundant levels of clay and marl, intercalating with carbonated levels, may be seen. Towards the central areas of the basin, the presence of gypsum with different characteristics from those in the "lower unit", can also be seen : lenticular, clastic sediment, crusts, ...

Upper Unit

In the area of study this unit can only be found in the Cerro del Viso (Alcalá de Henares). It extends to the S and NW and is located with unconformity on top of the "intermediate unit". The upper limit is roughly constituted by the so called "Limestones of the Páramos", although they are limited to an erosive unconformity covered by Pliocene clastic sediment.

During the deposit of the "Limestones of the Páramos", the NE edge of the basin ceases to act as a positive area and these limestones are finally deposited over the edge.

The facies in this unit correspond at the base to CAPOTE & CARRO (1968) "intramiocene fluvial system". They are evolved and canalized clastic sediment deposits. The lithology of these materials comprises quartzites, quartz, slate and schists in thick and sandy sizes. Abundant feldspars are to be added to the latter. These feldspars reveal the existing connection with the supplies of granites in the Central Range.

On the top we find "Limestones of the Páramos" of varied characteristics, which in the Cerro del Viso correspond to lacustrine micritic, oncolite and tufaceous limestones. The top of these is eroded and over them there are Pliocene clastic sediment deposits.

Outside the environment of our area of study and in this calcareous formation there is the locality of Cendejas de la Torre of Vallesian age.

In the north edge of the basin, there is a micromammal karstic locality of Ventian age (HOYOS *et al.*, in press) which infradate the tectonic phase. The latter affects this one and also the "Limestones of the Páramos" Iberomanchega Phase (AGUIRRE *et al.*, 1976). The limestones, by themselves, can be Vallesian or Turolian, but they can't be Middle Pliocene as it has been supposed by correlation with the Jucar Basin deposits (MEIN *et al.*, 1978)

SEDIMENTARY EVOLUTION

In short we can say that during the development of the "lower unit" this area of the Tajo Basin was fed by arid alluvial fans which came from the relief and then penetrated towards the centre of the basin where there was an ephemeral salt lake. The environmental conditions must have been extremely arid.

Towards the top of this unit, clastic sediment materials gradually invade the previous evaporite domains. Soluble salts disappear and a number of sebkhas move in, sometimes interconnected. Climatic conditions become milder, there is more fresh-water flowing into the basin, although still within significantly arid conditions.

During the development of the "intermediate unit", sedimentary conditions vary sensitively and the supply of rain water is more important although markedly seasonal. This gives rise to the greater progression of the fans over the centre of the basin and to the establishment of ponds and marshes in areas bordering the distal facies of these fans. The ponds and marshes, and even small pools, will become more important towards the top of the unit, remaining flooded for an increasingly longer period of time.

The only knowledge we have of the beginning of the "upper unit" is the existence of the "intramiocene fluvial system". Nevertheless, given the mineralogical composition of the sand in this fluvial system, we presume that the front of the Sierra continued the supply of clastic sediment materials by means of alluvial fans. Thus it can be confirmed that the climatic conditions continued to become more and more humid giving rise to a greater development of pools and lakes, on top of the unit. In the NE area of the basin, the contact between the Upper Unit and the Mesozoic edge can be clearly seen, due to the fact that the latter remains practically inactive.

FAUNA

The fossil fauna of the Miocene in the Madrid area (in San Isidro and Puente de Toledo) has been known since the middle of the last century (KAUP, 1840 ; EZQUERRA, 1840, 1841, 1845 ; MEYER, 1844 ; GERVAIS, 1853 ; PRADO, 1864). Later on, the fossil localities of the Puente de Vallecas and La Hidroeléctrica were discovered (HERNANDEZ-PACHECO, 1921 ; CRUSAFONT & VILLALTA, 1947 ; CRUSAFONT, 1952).

The age of these faunas has never been accurately established. MEIN (1977) has included them altogether in the MN 6 unit, under the name "Madrid".

The studies undertaken in the Tajo Basin, particularity in the area of Madrid, have led to the discovery of new faunas, some of them with macro and micromammal assemblages. Of these faunas only the ones in Moratines and Torrijos have been the object of preliminary publications (ALBERDI *et al.*, 1981 ; AGUIRRE *et al.*, 1982 ; Fig. 3).

BIOSTRATIGRAPHY

The genera *Armantomys* and *Lagopsis* characterize the micromammalian fauna of the Middle and Upper Aragonian in Madrid.

The fauna of Moratines (ALBERDI *et al.*, 1981), O'Donell, Arroyo del

	Paracuellos 3	Paracuellos 5	Henares 1	Henares 2	Arroyo del Olivar	Odonell	Moratines	Cantera de El Trapero
Soricidae indet.								12.5
Galerix sp.	5.5			4.5	2	3.5		
cf. Amphechinus sp.	1							
Heteroxerus rubricati							31	
Heteroxerus aff. rubricati		10	30					
Heteroxerus grivensis	10.5			27	2	6		
Armantomys sp.	35.5	3.5	10	16.5	20	3.5	20.5	12.5
Microdyromys koenigswaldi						3		
Pseudodryomys robustus				1.5	2	1	14	
Megacricetodon minor collongensis				3	4	18	14	
Megacricetodon minor minor		3.5						
Megacricetodon crusafonti	31.5	21						
Megacricetodon sp.			30					
Cricetidae cf. Megacricetodon								12.5
Fahlbuschia cf. koenigswaldi						20.5		
Fahlbuschia cf. darocensis	6		20					
Fahlbuschia sp.				6	35	1		
Lagopsis penai				40	35	43.5	20.5	
Lagopsis cf. verus	10	62						
Lagopsis sp.			10					62.5
Prolagus sp.				1.5				
Número total de dientes *	127	29	10	67	49	264	29	8
Número de kilos de sedimento lavado **	400	100	60	80	180	200	200	160

Table 1 - Distribution and percentages of the species of micromammals from Madrid faunas.

* Total number of teeth;

** Total weight of washed sediment in kilogrammes.

	Torrijos	Hidroeléctrica	San Isidro	Puente de Toledo	Moratines	Odonell	Henares 1	Arroyo del Olivar	Puente de Vallecas	Puente de Vallecas (C.R)	Paracuellos 5	Paracuellos 3
Amphicyon major	0.5	o							o	+		2.8
Amphicyon giganteus							+					
Hemicyon sansaniensis							+		o	+	3.8	
Pseudaelurus quadridentatus	1										0.7	1
Pseudaelurus lorteti					2.3				o			1
Sansanosmilus palmidens											0.7	
Protictitherium sp.											0.7	
Gomphotherium angustidens		15	+	+	2.3			+	2.5	+	10.5	0.2
Zygolophodon turicensis		o										
Anchitherium aurelianense	0.5	6	+	+	38.6		+	+	54.5	+	47	0.5
Aceratherium cf. tetradactylum										+	7	
Aceratherium simorrense												37
Dicerorhinus sansaniensis							+					2.8
Hispanotherium matritense	52.5			+								
Chalicotherium grande												2.5
Cainotherium miocaenicum			?		2.3	+						
Bunolistriodon lockharti		4.5		+	9				1			
Listriodon splendens											3	3.3
Conohyus simorrensis										+		
Suidae indet.	0.5	o					+		1.8			0.2
Triceromeryx pachecoi	18.5	69.5	+	+	36.5	+						
Paleomeryx cf. magnus									o			1
Micromeryx fluorensianus						+	+				1.5	4
Heteroprox aff. larteti		o	+	+			+		14	+	17.5	
Cervidae indet.												3.3
Miotragocerus sp.	26	o	+	+	6.8	+		+	26	+	5.3	
Caprotragoides sp.												40
Número Especies *	7	9	6	7	7	4	7	3	10	8	11	14
Número Restos Identificados **	184	152			45				431		131	391

Table 2 - Distribution and percentages of the species of macromammals from Madrid faunas.
o < 0.5 % ; * Number of species;
** Number of identifies remains.

Olivar and Henares 2, located at lower stratigraphic levels, are characterized by the assemblage of *Pseudodryomys robustus, Megacricetodon minor collongensis* and *Lagopsis penai.* These faunas can be correlated with a few in the Calatayud Basin : Valdemoro II_IB, Villafeliche IV and Las Planas IV A and B (de BRUIJN, 1967) in the Middle Aragonian (zones D and E *in* DAAMS & FREUDENTHAL, 1981), some of which are included in units MN 4 and 5 of the biozone of the Neogene continental Mediterranean (MEIN, 1977).

The assemblage of *Megacricetodon minor minor, Megacricetodon crusafonti* and *Lagopsis* cf. *verus* characterizes the micromammalian fauna of Paracuellos 3 and 5, located in upper stratigraphic levels. These faunas can be correlated with those of Manchones in the Calatayud Basin (de BRUIJN, 1967) which correspond to the Upper Aragonian (zone G *in* DAAMS & FREUDENTHAL, 1981) and unit MN 6 in MEIN (1977). The Henares 1 fauna shows *Megacricetodon* of large size, comparable with that of *M. crusafonti,* although it has particular morphologic characteristics. This leads us to ascribe to these faunas an age very close to that of Paracuellos 3 and 5.

The micromammalian fauna in the Cantera de El Trapero has not given, up to now, any taxonomically determinable material, at a specific level and for this reason it cannot be ascribed to any one of the faunistic assemblages.

The difficulty in differentiating two groups of fauna among Moratines, O'Donell, Henares 2 and Arroyo del Olivar is that there is no distinctive taxonomic element such as the ones used by MEIN (1977) to separate units MN 4 and 5 and the ones used by DAAMS & FREUDENTHAL (1981) to distinguish zones D and E in the Middle Aragonian. The faunal sequence in Calatayud can not be found in the area of Madrid where there are no *Cricetodon* or *Democricetodon.* In the O'Donell locality two species of *Fahlbuschia* co-exist. They used to be considered as successive in time (FREUDENTHAL, 1963). There too the two species *Heteroxerus* are associated with *Megacricetodon minor collongensis* (Table 1). Once again they were assumed as being successive in time (de BRUIJN, 1967 ; DAAMS *et al.,* 1977).

From a biostratigraphic point of view the macromammals in the area of Madrid confirm the attribution of these groups of localities to the Middle and Upper Aragonian. The replacement of *Bunolistriodon lokharti* by *Listriodon splendens* seems the most certain indicator to separate Paracuellos 3 and 5 from the rest of the localities and place them in the Upper Aragonian (LEINDERS, 1976 ; DAAMS *et al.,* 1977). Nonetheless, Paracuellos 5 shows notable differences in the Upper Aragonian fauna from the Calatayud-Daroca Basin but this could be attributable to environmental factors. On the other hand, in Paracuellos 3, together with *L. splendens,* we find various forms such as *Caprotragoides sp. (1), Aceratherium simorrense, Dicerorhinus sansaniensis, Palaeomeryx* cf. *magnus* which characterize the fauna of the Upper Aragonian in Manchones and Arroyo del Val IV-VI.

The most characteristic forms in the Middle Aragonian, together with *B. lokharti,* are *Hispanotherium matritense, Triceromeryx pachecoi* and *Cainotherium miocaenicum.* However we have not found any of the four associated in any of the fossil localities in the area of Madrid. In Torrijos there are two, as well as in La Hidroeléctrica, San Isidro and O'Donell. In the Puente de Toledo and Moratines there are three and in Vallecas only one.

(1) THENIUS (1979) claims that *Caprotragoides* corresponds to *Pseudotragus potwaricus* of Fort Ternan (GENTRY, 1970) and *Gazella stehlini* of the Vienna Basin (THENIUS, 1951). Without committing ourselves as to the validity of otherwise of this opinion, we use this term to describe the Bovidae of Paracuellos 3 which are similar to *G. stehlini.*

			MADRID AREA	Madrid - Guadalajara CORRIDOR	OTHERS TAJO BASIN
TUROLIAN	13 Ventian			ALGORA	
	12				
	11				
VALLESIAN				CENDEJAS	
ASTARACIAN	ARAGONIAN	Upper	PARACUELLOS 3 PARACUELLOS 5	HENARES 1	
ORLEANIAN		Middle	P. VALLECAS Aº DEL OLIVAR ODONELL MORATINES MADRID*	HENARES 2	TORRIJOS CORCOLES
		L.			
AGENIAN					LORANCA

* MADRID (S. Isidro, Pte. Toledo, Hidroeléctrica).

Table 3 - Biostratigraphy of the mammal localities of Miocene in the Tajo Basin.

Only the fauna in the Puente de Vallecas could be possibly considered more modern within the group in the Middle Aragonian. The arguments are nevertheless weak. They are based on the presence of a *Palaeomeryx* cf. *magnus* in Paracuellos 5 and Arroyo del Val IV, which appears to replace the *Palaeomeryx* cf. *kaupi* and the *Triceromeryx pachecoi.* Another fact is the absence of *Cainotherium miocaenicum* in Arroyo del Olivar, a fossil locality which can be stratigraphically correlated with the previous one. The abundance of *Heteroprox* could be another argument, since this form only becomes frequent from the boundary with Middle and Upper Aragonian. On the other hand, *Conohyus simorrensis* can not be interpreted in such a way (GINSBURG, 1977).

In any case we need more arguments to separate these Vallecas faunas from the others in the Middle Aragonian, especially when the assemblage of rodents in the Arroyo del Olivar is comparable with that of O'Donell and other fossil localities (Table 2).

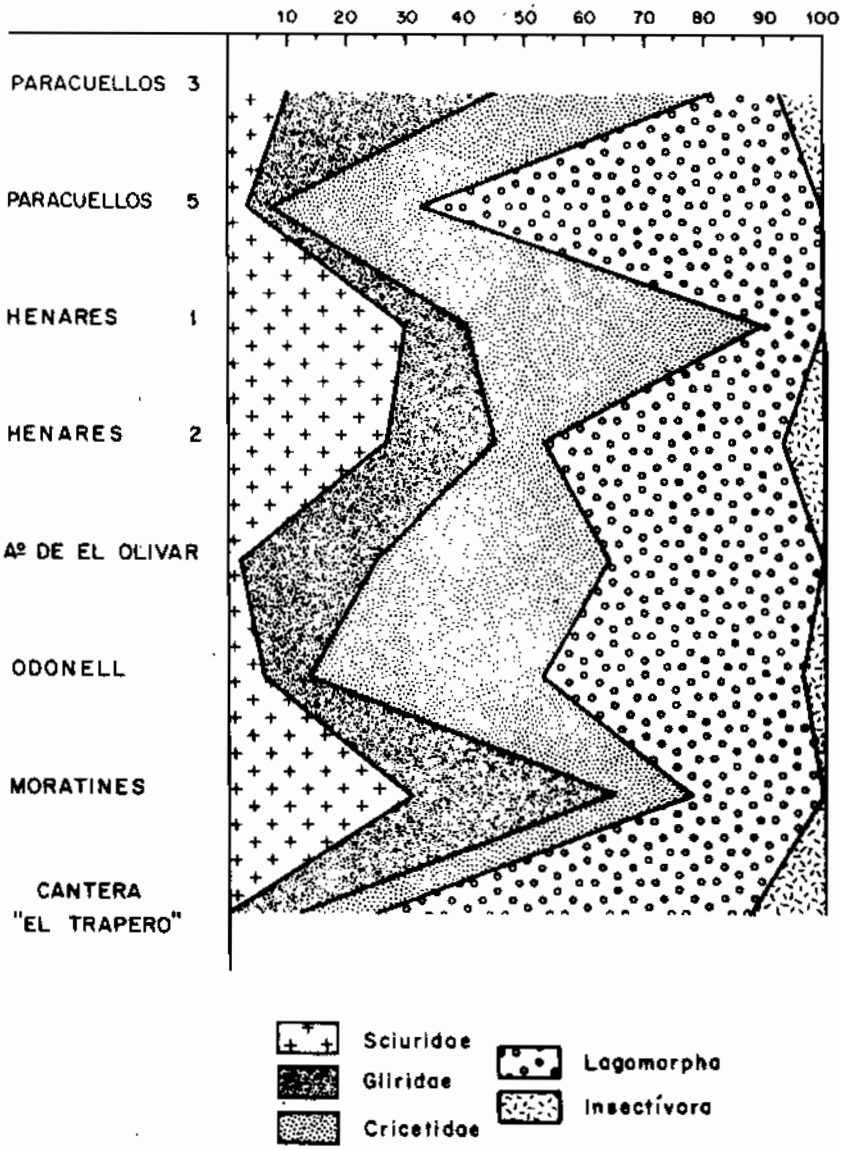

Fig. 4 - Faunas from Madrid : comparative percentage of the different micromammal groups.

Finally this group of faunas with macro- and micromammals corresponds, within the Aragonian, to the D-E-F area and the lower part of G (DAAMS & FREUDENTHAL, 1981). However in our fauna only two clear separations can be made :

- Moratines, O'Donell, Arroyo del Olivar, Henares 2, Hidroeléctrica, San Isidro and Puente de Vallecas could be compared with the areas D-E in the Middle Aragonian.

- Paracuellos 3 and 5 and, with reservations, Henares 1 correspond well to the F areas and the lower part of G belonging to the Upper Aragonian.

The fauna in Paracuellos 3 and 5 and Henares 1 could easily be included in unit MN 6, while the rest of the fauna could be indiscriminately included in MEIN's units MN 4 and 5 (ALBERDI & AGUIRRE, 1977). It is to say, they would correspond to Lower Astaracian and to Middle and Upper Orleanian respectively (FAHLBUSCH, 1976 ; Table 3).

PALAEOECOLOGY

An easily verifiable fact is the difference in behaviour between the assemblages of micromammals and macromammals. Micromammals change very little in time and space (Fig. 4). Equivalent species are progressively replaced while the quantitative composition, although varying from one fossil locality to the next, generally maintains a strong consistency.

This is not the case with macromammals (Fig. 5) where the assemblages change radically from one locality to the other. Torrijos has an assemblage of fauna widely dominated by *Hispanotherium*. In this case *Anchitherium* is very rare. In La Hidraeléctrica, *Triceromyx pachecoi* represents almost 70% of the findings. Moratines, Vallecas and Paracuellos 5 show a predominance of *Anchitherium*. Finally, in Paracuellos 3, the assemblage of *Caprotragoides* and *Aceratherium simorrense* is dominant over the rest of the species and, as in Torrijos, *Anchitherium* is practically absent.

For the moment the explanation for these marked differences remains unknown. In Torrijos and Paracuellos 3 the predominance of herbivores with hipsodontic or semi-hipsodontic teeth over those with braquiodontic ones is strongly marked. Both assemblages of fauna indicate an open dry landscape. Both localities are found in mud-flats associated with arkose channels. So, we may assume that this seasonably open and dry landscape would have streams with abundant water. These two localities represent the same lanscape in two different ages but the change in fauna, which has come about between the two, is remarkable. *Hispanotherium, Miotragocerus* and *Triceromeryx* have been replaced by *Averatherium simorrense* and *Caprotragoides*. *Hispanotherium* and *Triceromeryx* completely disappear and *Miotragocerus* is not found again until the Aragonian-Vallesian boundary in Catalonia. Therefore, there is no direct equivalence between these forms. *Hispanotherium* in its adaptation is very different from *A. simorrense* and *Caprotragoides* and, although its systematic classification is still debatable, it undoubtly belongs to a different tribe from the Boselaphini. The decadence of Palaeomerycidae must be explained by the adaptative radiation in other Pecora. It seems very possible that in the Upper Aragonian there was an entry of immigrant fauna to this open and dry Madrid Basin. There it replaced the pre-existing fauna. We are absolutely sure of the existence of this phenomenon in the Calatayud Basin.

The existing assemblages in Moratines, La Hidroeléctrica, Puente de Vallecas and Paracuellos 3 are clearly dominated by brachiodontic herbivores. We can think of a wetter environment for them, but not necessarily covered. Moratines and La Hidroeléctrica are in lacustrine facies, associated with lacustrine edges. Puente de Vallecas and Paracuellos 5, on the other hand are in facies associated with alluvial fans, but possibly at a greater distance from arkose channels than Torrijos and Paracuellos 3. In any case these fossil localities with brachiodontic herbivores differ from each other in their fauna composition. As we have pointed out before, in three of them : Moratines, Puente de Vallecas and Paracuellos 5, *Anchitherium* is the dominant herbivore. However, in Moratines it co-exists mainly with *Triceromeryx*, in Puente de Vallecas with *Miotragocerus* and *Heteroprox* and, in Paracuellos 5 with *Heteroprox* and rarely with *Miotragocerus*. The difference in age between Puente de Vallecas and Paracuellos 5 is well established. It is based on the change from *L. penai, M. collongensis* and *B. lokharti* to *L.* cf. *verus, M. crusafonti* and *L. splendens*. Nonetheless, from a quantitativ point of view, both assemblages are the nearest to the area of Madrid. La Hidroeléctrica seems atypical with its strong dominance of *Triceromeryx*.

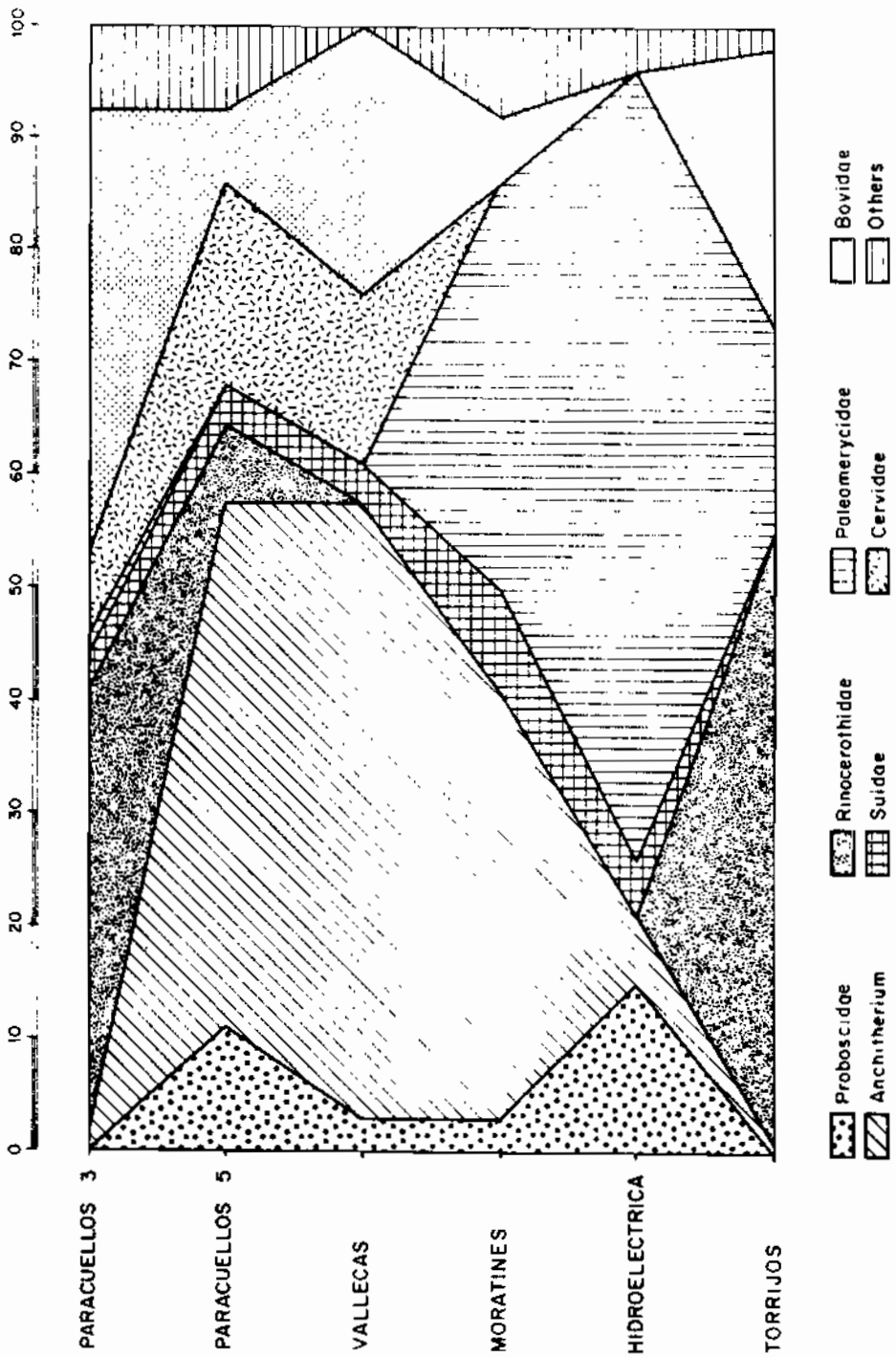

Fig. 5 - Faunas from Madrid : comparative percentage of the different macromammal groups.

These faunas also have in common the almost total absence of Rhinocerothidae and the best representation of Proboscidae. The most reasonable explanation, up to now, is that during the Middle Aragonian there has been a replacement of Palaeomerycidae by modern Pecora (Cervidae, Bovidae and Giraffidae). In our particular case, *Heteroprox* would have ousted *Triceromeryx* from the ecological niche occupied by brachiodontic herbivores of medium-large size, this

change marks in the fauna the period of the Middle Aragonian in Puente de Vallecas.

The ecological preferences of the assemblages of micromammals in the area of Madrid do not seem to contradict what has so far been put forward. During the period of time they cover they show, even less, diversification than in basins such as those of Calatayud-Daroca. This monotony in the composition seems to indicate a constant environmental climate and non observable changes in the weather. This would be confirmed by the fact that the replacements are made among species which can occupy the same ecological niche : *Megacricetodon minor collongensis* by *M. m. minor* ; *M. crusafonti* and *Lagopsis penai* by *L. verus.*

There is an absence of forms considered to be of a woodland biotope : Perauristinae, Eomiidae and *Democricetodon.* On the other hand, the kind considered to be of an open environment, such as *Heteroxerus, Fahlbuschia* and *Armantomys,* are dominant. A great abundance of *Lagopsis* shows the same general environment as that of the macromammals, that is, an open landscape with areas of water. Within this environment, the possibility of distinguishing a drier landscape from a wetter one seems somewhat more difficult. However, fossil localities considered to be more arid, such as Paracuellos 3, have fewer *Lagopsis* and many more *Armantomys.* On the other hand, the O'Donell, Arroyo del Olivar and Moratines fossil localities have very high percentages of *Lagopsis* and a greater diversity of Gliridae. Paracuellos 5, because of its great number of *Lagopsis,* would be closer to these latters.

BIOGEOGRAPHY

ALBERDI *et al.* (1981) have shown the existence of significant differences in the composition of fauna among the Spanish basins and their differences from other fauna in Europe for the Vallesian-Upper Aragonian. The central basins, in this case the Duero Basin -the Calatayud-Teruel Basin, are grouped in the same biogeographical unit, well differentiated from the Vallés-Penedés Basin and more closely related with the rest of Europe. The data obtained, to date, in the area of Madrid confirm this hypothesis and offer new accuracies. In the Middle and Upper Aragonian, the fauna in the area of Madrid only finds a comparable replica in the Calatayud-Daroca Basin. Thus, in the Middle Aragonian the most characteristic forms in the area of Madrid are *Lagopsis* and *Armantomys* as to micromammals and *Triceromeryx* and *Hispanotherium* as to macromammals. They are also found in the Calatayud-Daroca Basin. The exagerated predominance of *Lagopsis* over *Prolagus* is found in both areas. In the Upper Aragonian the situation could be similar ; in the area of Madrid, *Armantomys* and *Lagopsis* continue to be numerous, *Lagopsis* begins to be replaced by *Prolagus* in the Calatayud-Daroca Basin (LOPEZ MARTINEZ, 1977), but this is a very rapid replacement and it could be later than Paracuellos 3. In macromammals the forms we encounter are present in other European localities but it is in the area of Madrid and Calatayud-Daroca where they find a more favorable environment. This is the case with *Caprotragoides* and *Aceratherium simorrense,* forms which are very rare outside these two basins.

The comparison with other Iberian basins is more difficult. In Vallés-Penedés there could be an absence of all equivalent levels (AGUSTI, 1981). In the Duero Basin we have no report on the Middle Aragonian (LOPEZ MARTINEZ *et al.,* 1977 ; LOPEZ MARTINEZ & SANCHIZ, 1979). Differences appear in the composition between micromammals found in Upper Aragonian and those

found in the area of Madrid. A more covered environment is suggested by these faunas (LOPEZ MARTINEZ & SANCHIZ, 1979).

We may suppose that the fauna in the area of Madrid and Calatayud-Daroca can be included in the same biogeographical area, where the fauna was probably better adapted to a more open environment than those supposedly existing in European localities of this age.

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